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Climate Variability and Agricultural Productivity in MENA region

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Abstract

The Middle East and North Africa (MENA) region is particularly vulnerable to climate change. The severity of climate-change impacts is related to the geographic and ecological particularity of the region. The majority of countries in the MENA region belong to the hydraulic poor regions located between the tempered region of the Northern hemisphere and the inter-tropical region, characterized by scarcity and spatial and temporal rainfall variability. This paper describes, first, the interaction between climate changes, agriculture and food security in the MENA region. Second, an empirical model is used to test the impact of climate variability on agricultural productivity. Our results suggest that lower precipitation, heat waves and drought are the main causes of decreasing agricultural productivity in the region.

Keywords: agricultural productivity, climate change, MENA region, Malmquist productivity

JEL classification: O1, Q1, Q54, Q56

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1 Introduction

According to Intergovernmental Panel on Climate Change (IPCC) 2007, agriculture in many regions of the world will be severely hit by global warming, climate disruption, and extreme weather events. The negative effects of climate change on agriculture include increased crop damage from extreme heat, planning problems due to fewer reliable forecasts (uncertainty), increased soil erosion, increased moisture stress, and severe floods. Seasonal changes in rainfall and temperature could also alter growing seasons, planting and harvesting calendars. In addition, water availability for irrigation and drinking will be less predictable because rainfall will be more variable. It is possible also that salt from rising sea levels may contaminate the underground fresh water supplies in coastal areas.

Because of climate change, crop losses and therefore, food shortages, in many arid and semi-arid regions, such as the Middle East and North Africa (MENA) region, are likely to be more frequent. Climate change will affect agricultural productivity and food availability through two different channels. First, soil fertility will decline as the hydraulic conductivity of soil in the surface layer will be affected by climate-induced water stress. Indeed, water is vital to plant growth and historically, many of the largest falls in crop productivity have been attributed to sudden low precipitation events. Second, the variability in weather conditions could be a cause of low productivity as uncertainty inhibits innovation and imitation. Moreover, uncertainty about agricultural production will increase as extreme climate events, such as droughts and floods, are expected to be more frequent and cause more damage. As risky environment is pervasive in its effect on farming practices and farm performance, increasing uncertainty could discourage farmers upgrading production technology and therefore, affect productivity.

The impact of climate conditions on agricultural productivity is confirmed by many recent studies (Tao et al. 2003, 2008; Parry et al. 2004; Xiong et al. 2007; Schlenker and Lobell 2010). They show that a decrease in growing period water availability and water stress could play a major role in reducing agricultural productivity. FAO (2001) examined the effects of rainfall on food production and concluded that there are many interactions between climate variability and agriculture. Kumar et al. (2004), and Sivakumar et al. (2005) argue that varying precipitation patterns have a significant impact on agriculture. Das and Kalra (1995) evaluated the fertilizer and resource management for enhancing crop productivity under inter-annual variations in weather conditions. The results revealed sensitivity of crop yield to climatic variability.

The IPCC assessment report 2007, states confidently that the MENA region is extremely vulnerable to climate variations. The severity of climate-change impacts is related to the geographic and ecological particularity of the region. The majority of countries in the MENA region belong to the hydraulic poor regions located between the tempered region of the Northern hemisphere and the inter-tropical region, characterized by scarcity and spatial and temporal rainfall variability. Moreover, climate change in the MENA region is more than an issue of environment—it is a matter of development. The climate change will further exacerbate the situation in the region through reduced employment and higher food prices. Coping with the risk of food security will be beyond the capacity of many of the region's countries and is expected to add new challenges to the social agenda. Increasing agricultural productivity, therefore, will be a priority for MENA region to deal with the recurrent food security problem.

Although the impacts of climate change on the MENA region are likely to be more severe compared to other regions of the world, only a few studies on the effects of climate change on agriculture in the MENA region are available.

The goal of this study is to empirically evaluate the extent to which agricultural productivity in the MENA region, and therefore, food security, is affected by climate conditions. Our objective is to provide a comprehensive analysis of the magnitude of the challenge facing the region, and the likely impacts of climate change. Studying the impact of climate variability on agricultural productivity in a region suffering from food insecurity is extremely important as it allows policy makers to identify strategic actions to deal with the risks associated with climate change.

In order to measure the likely economic impacts of global warming, we use a statistical crop model to test the sensitivity of agricultural productivity to higher temperature and lower rainfalls.

Section two discusses the vulnerability of the MENA region to climate change and the likely impact of climate change on food security in the region. Section three empirically analyzes the potential impacts of climate change on agricultural productivity in the MENA region. The third section concludes and offers policy recommendations.

2 Vulnerability to climate change and food security in MENA region

2.1 Vulnerability to climate change

As one of the world's most water-scarce regions with a high dependency on climate-sensitive agriculture, the economic and social conditions in the MENA region are likely to deteriorate in the future. Higher temperature in the region will increase evaporation and cause the loss of surface water. This is particularly alarming considering that, in the quasi-totality of the aquifers, the groundwater level has already reached alarming values, and the water quality is at the lower limit of standard. Changes in extremes, including floods and droughts, are also projected to affect the water quality. Sea level rise is projected to extend areas of salinization of groundwater resulting in a decrease of freshwater availability for humans and the ecosystem in coastal areas (IPCC 2007).

An additional problem that, furthermore, complicates the situation in the region is the relative fragility of soil. The MENA region has a very high level of soil degradation as it is subject to contrasting climate factors like drought and short duration torrential rainfall, and increasingly important anthropogenic factors along the coast, in addition to inadequate cultural practices (Mtimet 1999). All these factors make the soil relatively fragile and longer periods of drought will accelerate desertification and shift the desert's limit further north, and therefore, decrease land areas suitable for agriculture.

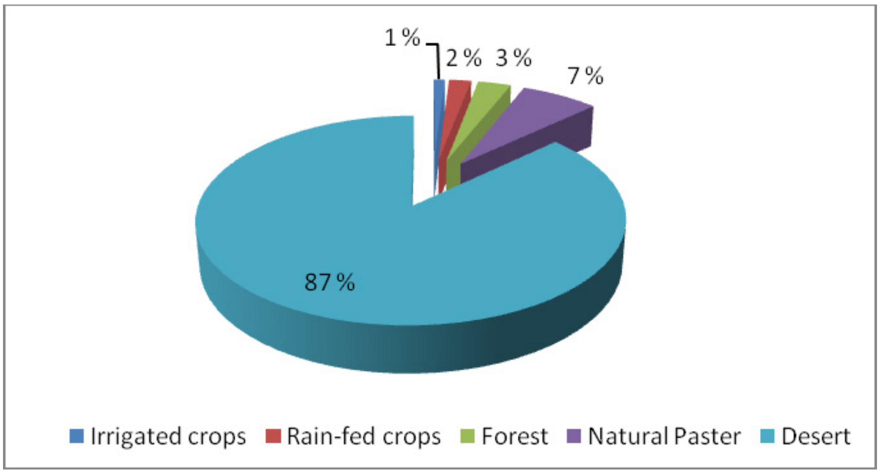
An important distinctive climatic feature of the region and one of the major factors that increases desertification is the Sirocco, a hot dry southerly wind that occurs around the year. The wind originates over the Sahara desert and blows north across the region. It contains a large amount of sand and dust and may cause serious damage to crops. Sirocco is very likely to be exacerbated by low rainfall and higher temperature. Drying and warming trends as well as depletion of the aquifer also contributes to desertification in the region.

The natural availability of water resources in the region determines whether extreme climate events like drought are a serious threat or not. However, infrastructure development, like the availability of improved drinking water and general accessibility of rural areas, determines the capacity of the region to cope with extreme events. According to the 2009 report of the Arab Forum for Environment and Development, 75 per cent of buildings and infrastructure in the region are at direct risk of climate change impacts. Moreover, the estimated proportion of the rural population having adequate access to a transport system is relatively low; thus populations in the region seem to be vulnerable to floods and droughts. Many countries also suffer from low access to drinking water in addition to underdeveloped infrastructure in rural areas. Therefore, longer and more frequent extreme climate events are likely to cause food shortage in rural areas.

2.2 Climate change, agriculture, and food security

Food insecurity in the MENA region is a recurring problem that is related, in part, to the geographical characteristics of the region. Indeed, according to World Bank, the MENA region is one of the world's most water-scarce regions. The region has a total area of about 14 million km2, of which more than 87 per cent is desert. It is characterized by a high dependency on climate-sensitive agriculture and a large share of its population and economic activities are located in flood-prone urban coastal zones. Furthermore, most people are city dwellers, not desert pastoralists.

Figure 1: Distribution of major land uses for the MENA region



Source: FAO (2008).

The region annually exceeds its supply of water from rainfall and river flows, depleting groundwater resources. Accordingly, the availability of water and subsequent agricultural production are expected to diminish (UNDP 2009). Warren et al. (2006) confirm that by 2025, 80–100 million people in the MENA region will be exposed to water stress. By 2050 water availability per capita will fall by 50 per cent and there is a high potential for food crises due to increasing demand (population) and declining supply factors (precipitation and yields). Indeed, the growing competition for water is expected to reduce the share of agriculture to 50 per cent by 2050.

Table 1: Population growth and water availability in MENA countries

	Population 1995 (million)	Water per capita 1995 (litres)	Population 2025 (million)	Water per capita 2025 (litres)
Algeria	28.1	527	47.3	313
Bahrain	0.6	161	0.9	104
Comoros	0.6	1667	1.3	760
Egypt	62.1	936	95.8	607
Jordan	5.4	318	11.9	144
Kuwait	1.7	95	2.9	47
Lebanon	3	1854	4.4	1261
Libya	5.4	111	12.9	47
Morocco	26.5	1131	39.9	751
Oman	2.2	874	6.5	295
Qatar	0.5	91	0.8	64
Saudi Arabia	18.3	249	42.4	107
Tunisia	9	434	13.5	288
UAE	2.2	902	3.3	604
Yemen	15	346	39.6	131

Source: Gardner-Outlaw and Engelman (1997).

According to many experts due to more frequent drought periods, agricultural performance is projected to drop in the future. The adverse impacts of climate change include reduced crop yield due to drought and reduced water availability. Increasing temperature trend will make crops fail to reach maturity due to lack of enough moisture in the soil. A warmer climate will also increase crop losses caused by weeds and diseases. Accordingly, because of the scarcity of water resources, yields are expected to fluctuate more radically and food security risk will be among the future challenges of the MENA region.

Diminishing water resources for agriculture will limit the capacity to feed the region's own population. Cline (2007) confirms that agricultural output is expected to decrease by 21 per cent by 2080 and in countries like Morocco and Algeria it could drop roughly by 40 per cent. The high salt content in much of the available water, on the other hand, with further complicate irrigation efforts, limiting the potential for additional development of irrigated agriculture in the region.

Furthermore, the region is largely dependent on the import of grain, meat, milk, sugar and oils, to meet the consumption needs of its population of 300 million. Food deficit is increasing and the reliance on external food sources has become a real constraint for most MENA countries. Consequently, any variations in food supply will have an impact, with possible social instability ramifications.

Table 2: Net cereal imports and food aid in MENA countries (% total consumption) 1998–2000

Algeria	76.10
Bahrain	39
Comoros	
Djibouti	100
Egypt	33.70
Jordan	97
Kuwait	99.60
Lebanon	88.40
Libya	89.20
Mauritania	
Morocco	54.10
Oman	98
Qatar	95.60
Saudi Arabia	72.90
Sudan	12.80
Syria	21.60
Tunisia	56.90
UAE	100
Yemen	76.30
Average	70

Source: FAO 2008; World Resources Institute.

In addition to the harsh environment, the region needs to deal with inefficiency with regard to food crops and productivity that results in particular from impractical farming methods, and weak training and education. Limited opportunities for financing and lending as well as misguided agricultural policies have resulted in a declining farm output. On the other hand, harsher living conditions in rural areas, due to the paucity of agricultural and rural development is likely to trigger massive rural–urban migration.

Finally, the degradation of agriculture is likely to increase unemployment in some countries where farm workers constitute about 30 per cent of the total labour force. Gender inequality is likely to increase because in many countries of the region, the share of women in the agricultural labour force is relatively high. Deteriorating living conditions of the poor are estimated to revive earlier social tensions and conflicts. It will, therefore, be necessary to introduce an integrated strategy that increases the options for controlling the demand on water resources and for encouraging their efficient usage. On the other hand, improving agricultural productivity will help to increase food supply and lower the reliance of the region on food imports.

In the following section, we study the impact of climate variability on agricultural productivity in the region.

3 Climate variability and agricultural productivity in MENA region

According to World Bank projections for the MENA region, temperatures will increase by about 2 degrees C by 2030 (4 degrees C by 2050), so that the sea will rise by 20-50 cm and rainfall precipitation will drop by 20 to 40 per cent by 2050. In addition, Agoumi (2003) confirms that since the beginning of the 20th century, drought frequency in North Africa has increased from one event every ten years to five or six occurrences. He also adds that between 6 and 25 million people in the region will be exposed to coastal flooding. Historical data confirm these predictions as annual mean temperature has increased (Figures A1 and A2 in the Appendix). Moreover, the frequency and severity of floods and heat waves in addition to years of recurring drought combined with the expansion of the Sahara desert into farmlands, confirm that climate change has already begun to affect the region.

Our study aims to test the impacts of climate conditions on agricultural productivity in the MENA region. The main object of the study is to use historical data on agricultural input and output to estimate the sensitivity of agriculture to climate variability and to determine the possible impacts of the projected climate change on agriculture in the MENA region. We proceed in the first step by estimating agricultural productivity. In the second step, we test the impact of different climate variables on agricultural total factor productivity.

3.1 Data and methodology

The analysis uses data from a balanced panel of 11 MENA countries over the period 1980–2007: Algeria, Egypt, Jordan, Mauritania, Morocco, Lebanon, Sudan, Syria, Tunisia, Turkey, and Yemen. The data come from the AGROSTAT system of FAO statistics division and the World Bank Development Indicators. The output variable is defined as the the value of agricultural production at constant price. We consider five input variables (Battese et al. 2004).

Land: this variable includes the arable land, land under permanent crops, and areas under permanent pasture and expressed in millions of hectares.

Machinery: this variable includes the total number of crawler tractors used in agriculture.

Labour: defined as the number of economically active population in agriculture.

Fertilizers: thousands of metric tons of nutrient units.

Livestock: defined as the sheep-equivalent of six categories of animals. We consider buffalos, cattle, camels, sheep, and goats. Data on the number of these animals is converted into sheep-equivalents using the following conversion factors: 8 for buffalos, cattle and camels, and 1 for goats.

To estimate total factor productivity in agriculture we use the nonparametric Malmquist DEA method. This approach has been widely used to measure agricultural productivity as it offers two major advantages. It does not require such kind of specification of a particular functional form for the objective function and allows for TFP decomposition into technical change, efficiency and scale change.

According to Färe et al. (1994) the output-oriented Malmquist Productivity Index measures the TFP change between two periods. It is defined as the function that measures the distance from a given input/output vector to the technically efficient frontier.

The Malmquist Index between period *t* and *t*+1 is defined as the geometric mean of two Malmquist indices:

$$M_0 = [M_0^t \times M_0^{t+1}]^{1/2} = \left[\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \times \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\right]^{1/2}$$

where D represents the output distance function which is defined as:

$$D_0^t(x, y) = inf_\theta\{\theta > 0 : (y/\theta) \in P^t(x)\}$$

$P^t(x)$ is the production possibility sets for any input set x.

The value of *M* is the Malmquist productivity index. The first term refers to the Malmquist index that measures TFP change over time with reference technology at time *t* and the second term measures the distance with reference technology at time *t*+1. A Malmquist index greater than unity indicates an increase of TFP, while an index less than unity indicates a TFP decrease.

The productivity change is decomposed in two components. The first component measures the change in technical efficiency between period *t* and *t*+1. The technical efficiency change is the rate at which a country moves toward or away from the production frontier. The second component measures the technological improvements between the periods. A technological index is greater, equal, or less than one when the production technology is improving, unchanged, or deteriorating respectively.

3.2 Estimation and results

Table 3 shows the mean level of output-oriented productivity change (tfpch) as well as technical efficiency change (effch) and technological change (techpch) under constant returns-to scale. The results suggest that the MENA region experienced an average decrease in total factor productivity by six per cent over the period 1980–2007. Without exception, productivity growth is negative and ranges between two per cent in Lebanon and Mauritania and nine per cent in Jordan and Turkey. In general, the MENA countries have preserved the same level of efficiency, while production technology has deteriorated in all countries. This means that the existing technology is deteriorating, and that technical efficiency is not improving. The low capacity to innovate and absorb new technology seems to be behind the low performance in agriculture. So, what may be the main factors behind the low capacity of the region to absorb new technologies in agriculture?

Table 3: Productivity scores

Country	techch	effch	tfpch
Algeria	0.93	1	0.93
Egypt	0.94	1	0.94
Jordan	0.91	0.999	0.91
Lebanon	0.97	1.016	0.98
Mauritania	0.98	1	0.98
Morocco	0.93	1	0.93
Sudan	0.93	1.007	0.94
Syria	0.95	0.996	0.95
Tunisia	0.95	1	0.95
Turkey	0.91	1	0.91
Yemen	0.94	1	0.94
mean	0.94	1.002	0.94

Source: Author's calculation.

As suggested by Battese et al. (2004), the existence of risk in the production environment affects decision-making by farmers in terms of their input-allocation decision. On one hand, decreasing productivity in agriculture associated with climate variability gives an incentive to farmers to invest in new technology. On the other hand, higher uncertainty about crop yields related to climate variability may divert investment away from agriculture to more profitable activities. The next step is to ask how historical productivity in the agriculture sector can be linked to specific climate conditions.

As argued by Lobell and Burke (2008), estimates of climate change impacts on agricultural productivity are often complicated by our ignorance of the contribution of different factors to plant growth. According to Monteith (1981), the main factors contributing to yield variation are temperature and rainfall. Specifically, the IPCC (2001) points out that crop yield responds to three sources of climatic variability:

- change in annual mean temperature and precipitation;
- change in the distribution;
- a combination of changes of the mean condition and the variability

Previous studies on agricultural productivity have also examined other actors such as: research and development, human capital, land quality, and irrigation (Frisvold and Ingram 1995; Gutierrez and Gutierrez 2003; Craig et al. 1997). The role of fertilizers and the use of machines in improving crop productivity are also recognized. Therefore, in addition to climate variables, we include the number of tractors per worker and the volume of fertilizer per hectare as determinants of agricultural productivity.

The general model to be estimated is defined as follows:

$$tfpch = \beta_0 + \beta_1 trend + \beta_2 machine + \beta_3 fertilizer + \beta_4 climate$$

where,

tfpch: is total factor productivity in agriculture.

trend: is time trend to capture possible extrenal technological progress.

machine: is defined as the number of tractors per worker. We expect that the use of machines by farmers contributes to increase productivity.

fertilizer: is defined as the volume of fertilizer per hectare. We expect that the use of fertilizer improves crop yields.

climate: represents different measures of climate variability.

As suggested by the litterature we include two groups of climate variables. The first group of climate variables reflects the effects of precipitation and temperature levels on productivity. Data on precipitation and temperature are defined as the average temperature and the total rainfall during the growing seasons, respectively. To take into consideration the likely non-linear effects of precipitation and temperature, we use a quadratic function.

The second group of climate variables measure the impacts of the weather variability on productivity. We include two forms of rainfall variability:

- Inter-annual rainfall variability: the annual deviation from long-term averages.
- Intra-annual rainfall variability: the distribution of rainfall within a year.

We use a coefficient of variation, defined as the ratio of intra-annual average over the intra-annual variation, to approximite the variations in intra-annual distribution of climate variables. We suppose that the distribution of temperature and precipitation over the growing season has an impact on the growing cycle and therefore on crop yields.

To take into consideration the impacts of extreme climate events, such as heat waves and drought, we include the maximum and minimum levels of temperature over the growing cycle and a measurement of dryness. We use a dummy variable to test the impact of drought. The dummy variable takes the value of one if total precipitation over the growing cycle is less than 70 per cent of the long-run average and zero otherwise.

The time-series for climate variables used here come from Tim Mitchell from Tyndall Center for Climate Change and NOAA/WMO site, which provides very detailed daily weather data (Mitchell et al. 2003). They include daily precipitation (rain or snow), temperature, wind, and humidity data for several decades[1].

As a priori there are no theoretical reasons to consider a specific estimator, we estimate both random-effects and fixed-effects models. We use Hausman test to choose between the fixed effects and the random effects. We estimate four different model specifications and test the effects of technology and climate variability on productivity change. Results for the four specifications are presented in Table 4.

[1] http://www.ncdc.noaa.gov/cgi-bin/res40.pl?page=gsod.html

Table 4: Estimates for the determinants of agricultural productivity

	Model 1	Model 2	Model 3	Model 4
Constant	0.739***	0.787***	0.774***	1.063***
	(0.27)	***-0.06***	***(0.049***	***(0.158)***
Time trend	0.003***	0.003***	0.004***	0.004***
	(0.0006)	***-0.0006***	***(0.0007)***	***(0.0008)***
Tractors per worker	0.420**	0.418**	0.420*	0.404*
	(0.202)	***-0.207***	***(0.205)***	***(0.227)***
Fertilizer per hectare (metric tons)	0.010*	0.011**	0.011**	0.011**
	(0.005)	***-0.005***	***(0.005)***	***(0.005)***
Precipitation	0.0003*			
	(0.001)			
Precipitation^2	-4.50e-07*			
	(2.41E-07)			
Temperature	0.016			
	-0.026			
Temperature^2	(0.0007)			
	(0.00067)			
Precipitation:		0.109		
intra-annual distribution		***(0.013)***		
Temperature:		-0.007		
intra-annual distribution		***(0.009)***		
Precipitation: Deviation to long-run mean			-8.08E-06	
			(0.00006)	
Temperature: Deviation to long-run mean			-0.014**	
			(0.007)	
T_max				-0.007*
				(0.004)
T_min				-0.1007
				(0.006)
Drought				-0.023**
				(0.011)
Wooldridge test for autocorrelation in panel data	2.285 (0.1616)	1.479 (0.2519)	1.75 (0.2453)	1.335 (0.2748)

Source: Author's calculation.

It is well-known among experts that the slow breakdown of organic matter is a natural source of support for high productivity over time. Greenland et al. (1992), for instance, argue that faster breakdown of soil organic matter into its mineral components depends on sufficient moisture for biotic activity of any kind. In addition, the efficiency with which fertilizer nutrients are deliverable to the plant depends on the soil ability to retain moisture and deliver the nutrients which in turn depend largely on soil organic matter.

Battisti and Naylor (2009), on the other hand, show that higher growing season temperature can significantly impact agricultural productivity, farm income and food security. Indeed, it was proven that an increase in atmospheric carbon dioxide has a fertilizer effect on crops, and that it improves productivity. However, Alexandrov and Hoogenboom (2000) confirm that the expected increase in temperature may reduce the growing cycle and lead to decrease in crop productivity.

As it is shown in the first column in Table 4, only precipitation turns out to be a significant factor explaining variability in total factor productivity change. The effect of rainfall during the growing season is nonlinear and the threshold level after which the impact becomes negative is 335 mm. We find no statistical evidence of the effect of the intra-annual distribution of precipitation and temperature on productivity change. In addition, the deviation of precipitation to the long-run seems not to be significantly related to productivity changes.

The average growing season temperature has no significant effect on agricultural productivity in the region, while positive deviations of temperature relative to the long-run level contribute significantly and negatively to productivity change. These findings may be explained by the fact that current ambient temperature in the region is already close to the physiological maximum for crops. Therefore, higher temperature will influence negatively the rate of plant phonological development, the length of growing period and rates of evaporation and transpiration. In addition, considering the small variations in annual temperature, the effect of increasing temperature may be felt only in the long-run.

Consequently, the expected lower precipitation and higher temperature will result in the decline in total factor productivity, especially if we know that the majority of the countries of the region devoid of any major river systems.

Many experts confirm that the very damaging risks from climate change arise essentially from an increasing likelihood of extreme events, like droughts and floods, and less from a gradual change in average conditions. Indeed, plants can withstand a dry spell with little loss of yield, but a prolonged drought will destroy the entire crop. Fuglie et al. (2007) argue that during the past 60 years, the lowest levels of agricultural productivity in the US are highly correlated with severe drought episodes. As it is shown in Table 4, drought episodes in the region were damaging to productivity. Indeed, a severe water stress during the growing season causes on average a decrease of 2.3 per cent in agricultural total factor productivity. Accordingly, the likely increase in frequency and severity in such an extreme climate event will be a substantial challenge that the MENA region needs to address.

On the other hand, Wheeler et al. (2000) argue that only few days of extreme temperature at the flowering stage of many crops can drastically reduce yields. The negative and significant effect of maximum level of temperature during the growing season confirms that an increasing frequency of the heat waves may be very harmful to agricultural productivity in the region. Indeed, changing in short-term temperatures can be critical if they coincide with key stages of plant development.

Finally, the biophysical conditions explain current agricultural productivity to the extent that technological progress can overcome location-specific constraints. We find that the coefficients associated with the variables, tractors per worker and fertilizers per hectare,

are significantly positive. This confirms that despite the current hard climatic conditions in MENA region, using technology may help to improve productivity.

Increased investment in machinery and fertilizers, despite the decline in productivity, reflects the willingness of governments in the region to boost agricultural production, through subsidies to farmers, in order to ensure the continuity of food supply. However, the increasing number of tractors in use per agricultural worker and the volume of fertilizers per hectare contradict with decreasing total factor productivity (Figure A2 in the Appendix). This suggests that the current technology used in agriculture is less than sufficient to overcome the negative impact of climate variability on agricultural productivity in MENA region. The use of obsolete technology by farmers suggests that risks associated with agricultural activities are real constraints that prevent investment in better technologies.

4 Conclusion

The biophysical conditions, the socioeconomic conditions as well as the state of technology in the region are the main factors behind the extreme vulnerability of the region to climate change. Particularly, water scarcity is a main constraint to improve agricultural productivity in MENA region. Indeed, over 90 per cent of agriculture in the region is rainfed and there is no potential for additional development of irrigated agriculture because of water scarcity. The problem is more acute in view of the increasing urbanization, growing population and the already high rates of water use. In addition, the high salt content in much of the available water further complicates irrigation efforts. Traditional cultural practices are dominant and access to new technology by the majority of farmers is quite limited. Consequently, a small reduction in rainfall associated with climate change could cause a sharp decrease in agricultural production and shortage in food supply, particularly for smallholders in rural areas.

Over the centuries, farmers in MENA region have responded deftly to climate change, however, with modern life and economic progress their capacity to cope with climate variations has declined. The situation in the region is further compounded by the fact that MENA region has a low capacity to adopt, both technologically and financially.

We used Malmquist methodology to test the contribution of climate variability to agricultural productivity. Our results confirm that agricultural performance is decreasing, and that inefficiency is the main cause of regress in productivity. We confirm that lower precipitation and more extreme events, such as droughts and heat waves, contribute to explain the lower performance in agriculture in the region. In addition, our results suggest that the uses of tractors and fertilizers help to improve agricultural productivity.

Lower agricultural productivity and increased water competition will add to the region's difficulties to feed its growing population. In addition to the harsh environment, the region needs to deal with inefficiency with regard to food crops and productivity that results in particular from impractical farming methods, and weak training and education. Limited opportunities for financing and lending as well as misguided agricultural policies have resulted in declining farm output. On the other hand, harsh living conditions in rural areas, due to the paucity of agricultural and rural development has triggered massive rural–urban migration.

Coping with the risk of food security will be beyond the capacity of many of the region's countries and is expected to add new challenges to the social agenda. Deteriorating living conditions of the poor are estimated to revive earlier social tensions and conflicts. It will, therefore, be necessary to introduce an integrated strategy that increases the options for controlling the demand on water resources and for encouraging their efficient usage.

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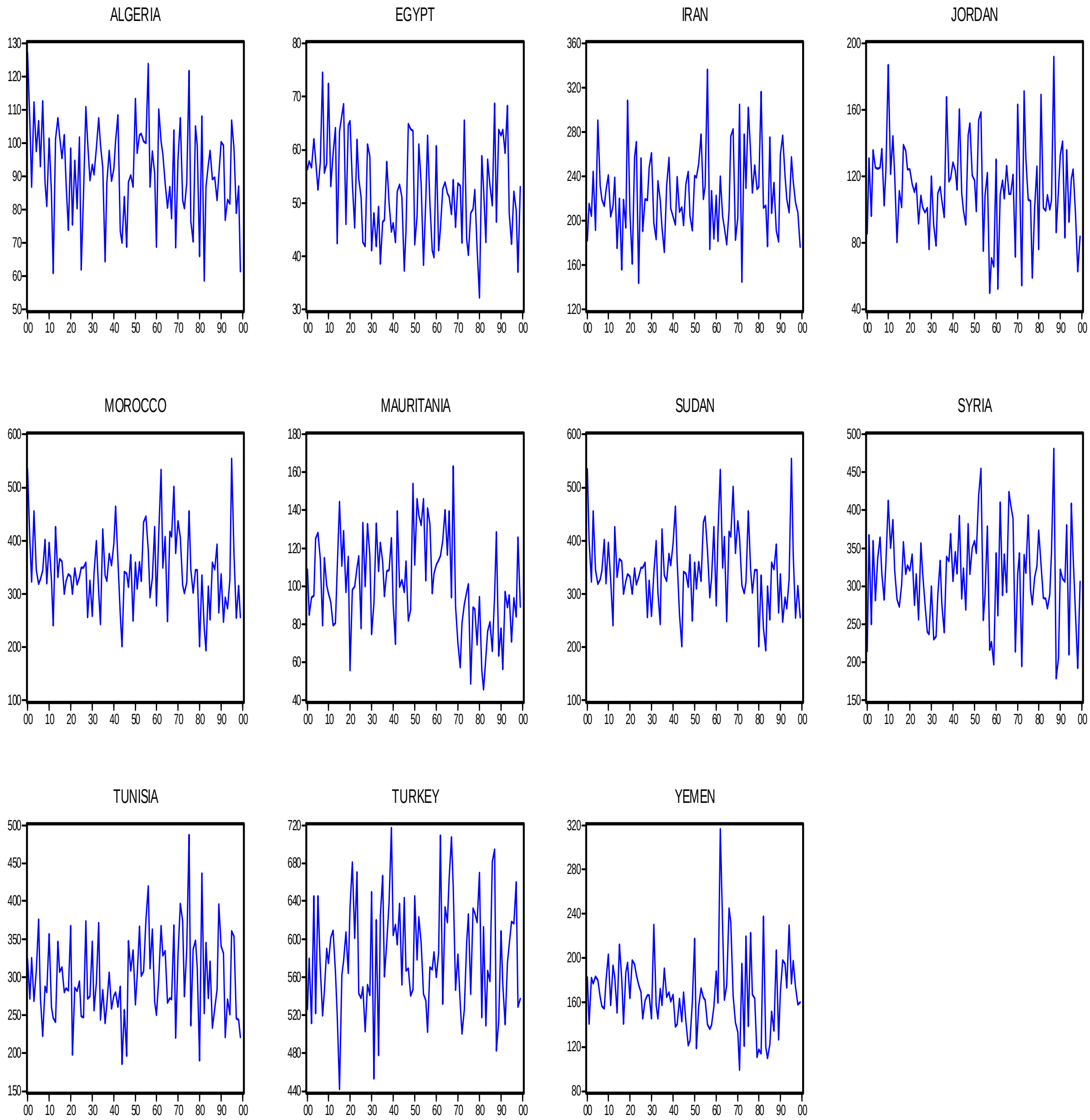
Appendix

Table A1: Descriptive statistics of productivity scores by country

Country	Mean	Std. Dev.	Min	Max
Algeria	0.93	0.05	0.76	0.97
Egypt	0.94	0.04	0.80	0.99
Jordan	0.91	0.05	0.74	0.95
Lebanon	0.98	0.04	0.92	1.07
Mauritania	0.98	0.21	0.76	1.68
Morocco	0.93	0.04	0.77	0.96
Sudan	0.94	0.11	0.65	1.11
Syria	0.95	0.04	0.82	1.00
Tunisia	0.95	0.06	0.77	1.02
Turkey	0.91	0.06	0.72	0.95
Yemen	0.94	0.08	0.71	1.02

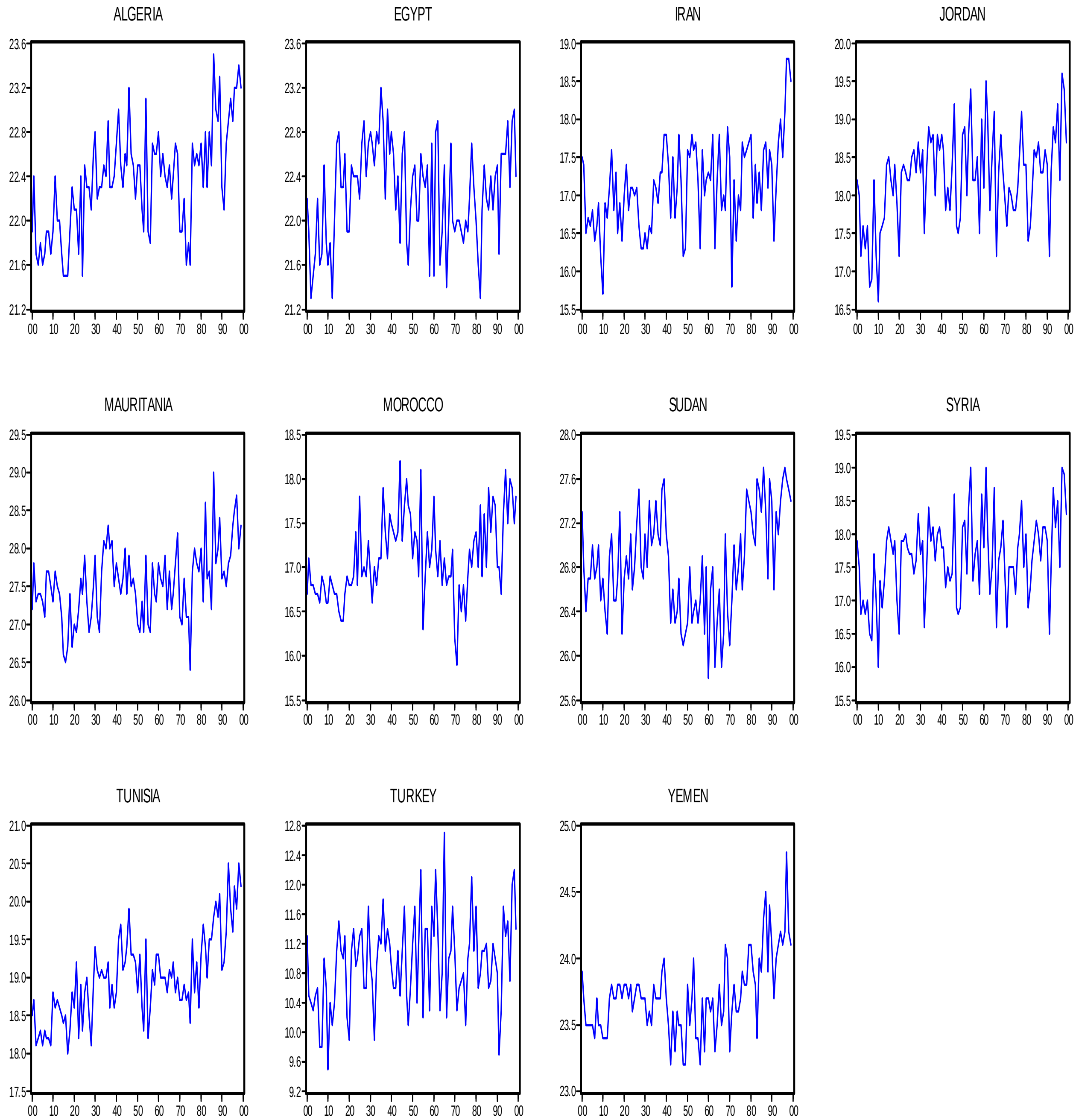
Source: Author’s calculation.

Figure A1: Average annual precipitation by country, mm per year (1900–2000)



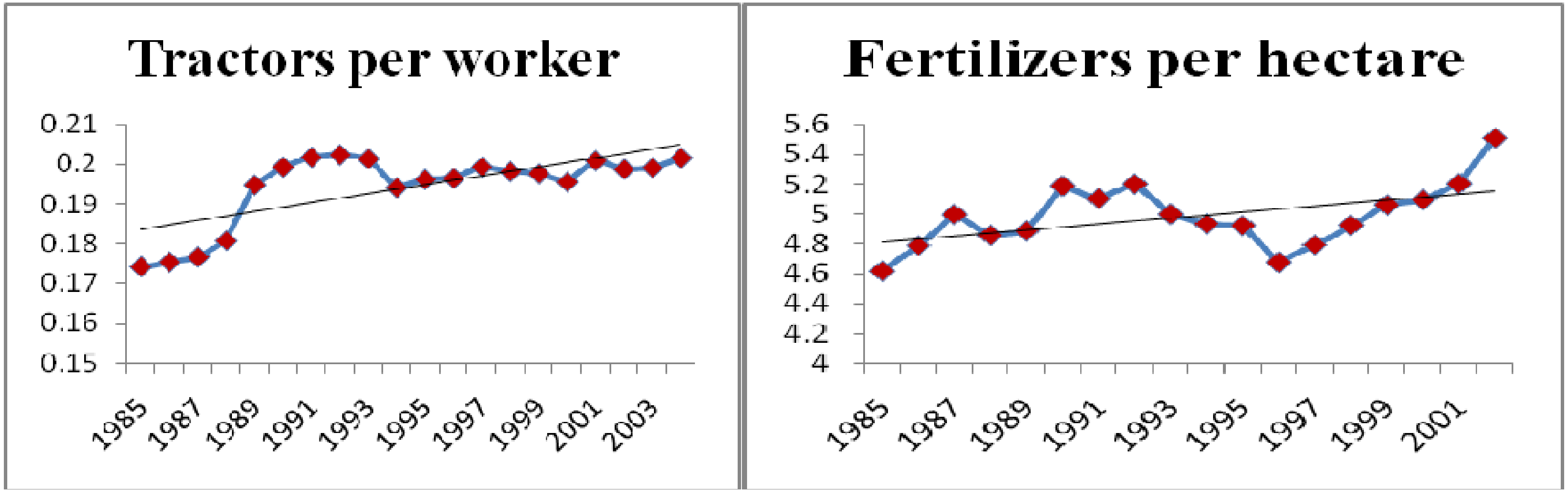
Source: Tyndall Center for Climate Change and NOAA/WMO.

Figure A2: Average annual temperature by country, mm per year (1900–2000)



Source: Tyndall Center for Climate Change and NOAA/WMO.

Figure A3: Tractors per worker and fertilizer use per hectare, metric tons



Source: FAO (2008).